UPPER OCEAN MIXING DUE TO NONLINEAR INTERNAL WAVES OF THE CONTINENTAL SHELF

Tim Stanton
Department of Oceanography
Code OC/St, Naval Postgraduate School
Monterey, CA 93943
phone: (408) 656 3144fax: (408) 656 2712email: stanton@oc.nps.navy.mil
Award#: N0001497WR30045

LONG-TERM GOALS

My long term goals are to observe and model wave and boundary layer processes which contribute to turbulent mixing in the coastal ocean using new instrumentation techniques.

SCIENTIFIC OBJECTIVES

Scientific objectives of this project are to study the mechanisms by which internal tides and associated solitons contribute to turbulent mixing in the pycnocline and ocean mixed layer. Secondary objectives are to characterize coastal solitons, and to investigate the interaction of surface gravity waves and internal solitons, and the resulting near-surface turbulence.

APPROACH

A three week observation of the upper ocean near the shelf break off northern Oregon was made from FLIP in October 1995, while it was tri-moored in 150m of water during the Coastal Ocean Probing Experiment (COPE), run by NOAA's Environmental Technology Laboratory. Over 18000 profiles of temperature, salinity, and thermal and kinetic energy dissipation rates were measured by an automated Loose-tethered Microstructure Profiler once a minute, allowing the upper ocean stratification and turbulence levels to be observed. Five *in situ* measurements of (u,v,w,T,C) were made across a 5m aperture spanning the shallow, strongly stratified pycnocline, while a high speed five beam Broadband Acoustic Doppler profiler defined the velocity structure below the *in situ* array. These measurements were optimized to study energetic solitons which were generated near the shelf break and propagated shoreward past FLIP.

WORK COMPLETED

Reduction of the large LMP and BADCP profile timeseries into binned and calibrated profiles was completed last year. Processing of the current sensor timeseries required a significant programming effort to identify and correct a data acquisition buffer problem. These data have been shared with other COPE investigators looking at surface effects of the internal wave field.

Additional processing had to be executed to transform the three component velocity measurements into vertical coordinates due to strong tilts of the instruments forced by the very large velocities associated with the solitons. A workshop of the COPE participants was hosted at NPS in August 1996 to disseminate data sets and work on collaborations. Analysis of a 24 hour segment of data characteristic of the strongest internal tidal energy was used in a paper submitted to Science (Stanton and Ovstrovsky 1997a). Nearsurface current timeseries from several representative Solitary Iinternal Wave (SIW) packets through the three week observation period were compared with radar backscatter observations made by the NOAA ETL group in Kropfil *et al*, 1997. A more comprehensive manuscript describing the critical stability and amplitude of the strong SIW packets and the net effect on upper ocean mixing will be submitted in late 1997 (Stanon and Ovstrovsky 1997b). These results will be summarized at the 1998 Ocean Sciences meeting.

RESULTS

The strong, shallow, salinity stratified surface structure at the COPE site provided conditions which supported large amplitude soliton packets on the steep leading edge of each cycle of the semidiurnal internal tide observed during the observation period. Stanton and Ostrovsky, 1997a, show that during periods of strongest offshore tidal forcing, and greatest internal tide dispalcements, the SIW displace the pycnocline down approximately 20m from it's 7m initial depth, causing cross-shore surface currents in excess of 75 cm/s. These displacements are only poorly described by KdV theory, in contrast to a good fit with the next order comKdV form. Figure 1 shows a profile timeseries of temperature over a 1.8 hour period spanning the start of one of the SIW packets, with the 15 - 25m downward displacements of the shallow pycnocline clearly seen. The nominal pycnocline depth, local buoyancy frequency and thermal and turbulent diffusivities on the $\sigma_\Theta = 23.4$ isopycnal surface are shown in Figures 2a - d for the same interval. A one to two order of magnitude change in turbulent diffusivities in the pycnocline can been seen in Figures 1c and d as the SIW packet propagates past the fixed observation point.

Kropfli *et al* analyzed land-based doppler radar data operated by ETL to study the modulation of backscatter intensity and doppler frequency caused by the highly nonlinear SIW packets. Under certain conditions, the modulation of short wind wave amplitudes during the passage of the SIW could be clearly seen.

Stanton and Ovstrovsky, 1997b, have analyzed five other wave packets with differing displacements, stratification and wind forcing conditions over the three week observation period to study the shear stability of the SIW displacements and the net contribution to turbulent dissipation of the waves, and to vertical mixing in the upper water column.

IMPACT / APPLICATIONS

Solitons associated with internal tidal energy are ubiquitous over stratified coastal shelves. They have been difficult to observe due to their short period and the short duration of the packets. The combination of the strongly stratified site, the stable platform provided by FLIP, and continuous spatial radar coverage of the site are providing insights into the properties of these wave packets and their effects on surface water mass displacement and vertical mixing in the upper coastal ocean.

TRANSITIONS

This research was a component of the DoD funded radar remote sensing project, COPE, managed by the NOAA ETL laboratory, which was designed to broadly study environmental effects impacting surface scatter of high frequency radars. Data from the experiment have been made available to investigators studying radar backscatter properites of the ocean, air-sea interactions in coastal regions and studies of the ocean “thermal skin”.

RELATED PROJECTS

Tdata from this project are being used in on-going radar backscatter studies, and to met the objectives of air-sea interaction projects including the ONR MBL program.

REFERENCES

Kropfli, R. A., L. Ostrovsky, T. Stanton, E. Skirta, and A.N. Keane , “Relationships Between Strong Internal Waves in the Coastal Zone and their Radar Signatures”, submitted to J. Geophys. Res., 1997.

Stanton, T. P. and L. A. Ostrovsky, “Observations of Highly Nonlinear Internal Solitons Over the Continental Shelf”, Submitted to Science, 1997a.

Stanton, T. P. and L. A. Ostrovsky, “Contribution of Highly Nonlinear Solitary Internal Waves to Coastal Mixing.”, 1997b, In prep.

WEBSITE

http://www.oc.nps.navy.mil/~stanton/turblab.html

File Contains Data for PostScript Printers Only

Figure 1 A 1.8 hour profile timeseries of thermal structure as a SIW packet passes FLIP

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Figure 2 a.) Depth of the $\sigma_\theta = 23.5$ isopycnal for the same period as figure 1. b.) Buoyancy frequency on this isopycnal. C.) Turbulent diffusivity based on turbulent kinetic energy dissipation rates and a mixing efficiency of 0.2 in the Osborn / Cox model. d.) Turbulent thermal dissiaption rate-based vertical diffusivity in the pycnocline for the same interval.